Early Journal Content on JSTOR, Free to Anyone in the World

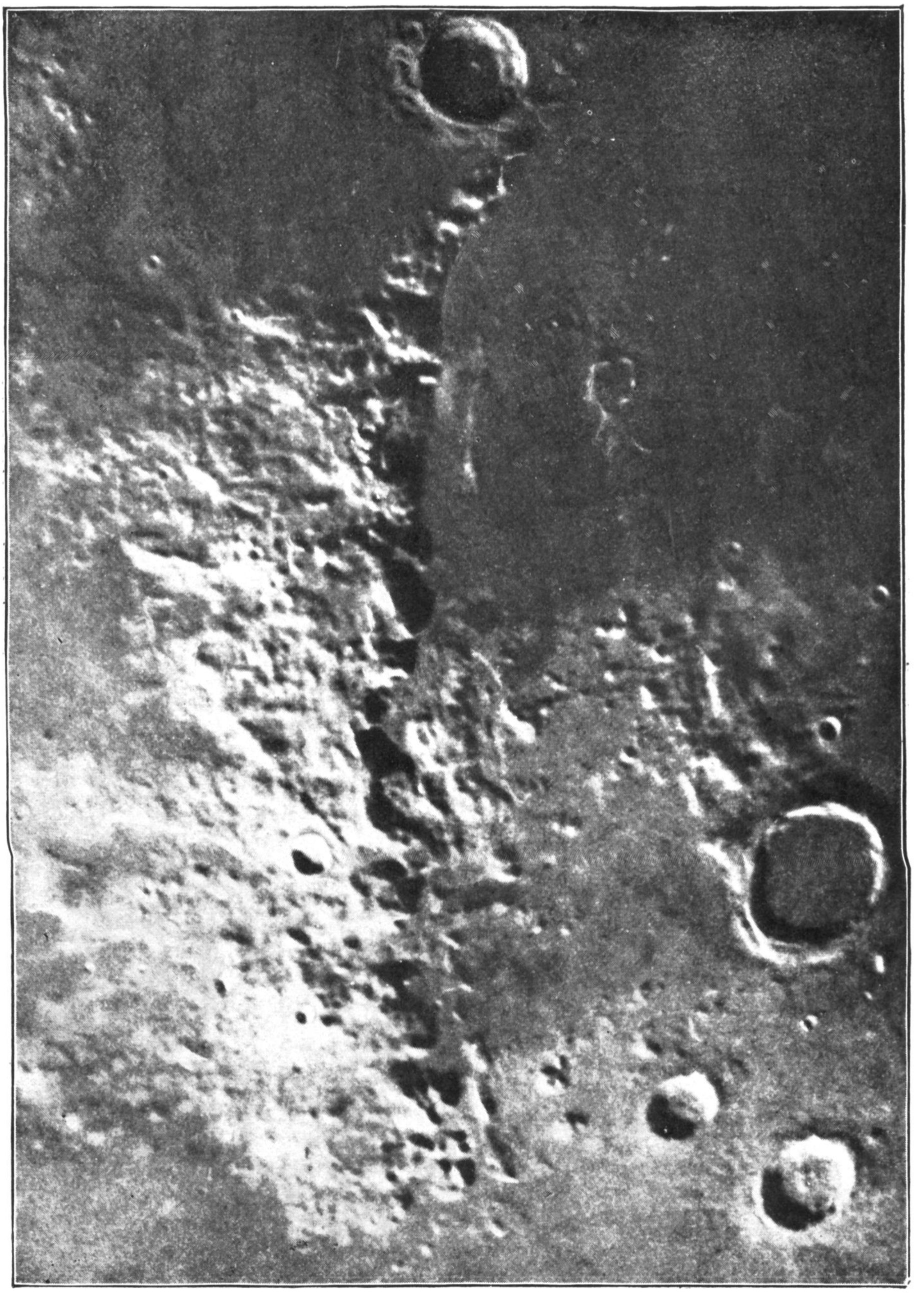
This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.



FROM A NEGATIVE TAKEN AT THE LICK OBSERVATORY, 1891, JULY 14.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. VII. SAN FRANCISCO, CALIFORNIA, JUNE 1, 1895. NO. 42.

THE MOON AS SEEN BY A GEOLOGIST.*

[Abstract of a Paper by Professor EDWARD SUESS, entitled "Einige Bemerkungen ueber den Mond," printed in the *Sitzungsber. d. k. Akad. d. Wissenschaften in Wien*, February 1, 1895.]

Professor SUESS, the eminent Austrian geologist, communicated, on February 7th of this year, to the Imperial Academy of Sciences at Vienna, a paper on the Moon, considered from a geological standpoint. As a basis for his observations and conclusions, he used the famous lunar photographs of the LICK Observtory, enlarged by Professors WEINEK and PRINZ, and those made by Messrs. LOEWY and PUISEUX, at the Paris Observatory, which latter were also enlarged by Professor WEINEK. These photographs will be designated as L. W. (LICK-WEINEK), L. P. (LICK-PRINZ), and P. W. (Paris-WEINEK).

Professor SUESS starts with the reasonable hypothesis that the mineral matter covering the surface of the Moon is similar to the volcanic rocks of our Earth. If this be true, we perceive at once that, since our basaltic rocks—for example, the lavas of Hawaii—reach a specific gravity of 3.3, and the specific gravity of the mass of the Moon averages only 3.4, we can only assume the existence of our lighter, acid rocks on the surface of the Moon.

LANDERER'S observations, comparing the angle of polarization of our acid terrestrial rocks with that of certain large, gray plains on the Moon—for example, *Mare Nectaris*, *Crisium*, *Fecunditatis* and *Tranquillitatis*—seem to confirm the correctness of this hypothesis. He found that the angle of polarization of these plains is 33° 17′, while terrestrial observations gave the following values, viz.: For *basalt*, 31° 43′; *trachite*, 32° 16′; *andesite*, 32° 50′; *vitroporphyry*, 33° 18′; *hyalomelan*, 33° 39′; *obsidian*, 33° 46′; and *ice*, 37° 20′.

---

* Translated for the *Publications* A. S. P., by Mr. C. A. STETEFELDT. The footnotes of the original, which give bibliographic references, have usually been omitted here; a few have been added.

We have further to consider that the intensity of gravitation on the Moon is only one-sixth of that on Earth; hence, magmatic differentiation of lavas must be less on the Moon. Finally, there is no atmospheric pressure on the Moon to counteract explosions, and to check evaporation; and the great difference in temperature between day and night must have influenced the forms of solidification. All these conditions seem to have favored the intensity of volcanic action, and to have produced the bizarre forms of craters on the Moon.

In concluding the introduction of his paper, Professor SUESS pays a high tribute to our Professor DANA, who, nearly half a century ago, and before large photographs of the Moon existed, compared the volcanoes of Hawaii with those of the Moon, recognizing many peculiarities which they have in common.

The light reflected by different parts of the Moon presents great differences in intensity. Selenographers have attempted to express these degrees of intensity by a scale from 0° to 10°. According to NEISON, 0° refers to dark shadows; 1°, an almost black-gray, is rare; 2° and 3° appear, for example, in *Mare Crisium*, in parts of *M. Tranquillitatis*, and on the edge of *M. Serenitatis*. The majority of mountains and their interior plains range between 4° and 6°. Grades of 7° and above are comparatively rare, and do not correspond to large surfaces, but to spots, points, craters, etc.; only a few points reach 9°, and 10° is confined to the interior of *Aristarchus*. Neglecting details, it can be said that the plains are more or less dark, mountains lighter, and that the brightest portions are scattered and locally confined. It has been generally conceded that the latter are of most recent origin.

It would not be difficult to classify terrestrial volcanic products according to their colors. *Obsidian* and the great mass of basaltic rocks would come under 1° and 2°; medium gray tones would be represented by *trachytes* and *andesites*; while, from 7° upward, we would not have real lavas, white *rhyolites* excepted, but fumaroles and their by-products, pumice-stone and certain white volcanic ashes. Hence, rocks of the brightest colors, confined to limited areas, are of the latest origin on the Earth also.

How far are we allowed to compare these color-scales? As previously stated, we are not justified in assuming the existence of our heavy, black, basaltic lavas on the Moon, and for this reason we are somewhat in doubt in regard to the interior of those lunar craters which come under 1° and 2° of the color-scale; for example, some dark spots on *Mare Vaporum* and the dark interior of *Plato* and *Boscovich*. On the other hand, an undoubted agreement exists between lunar and terrestrial volcanoes for the lighter and brightest colors. Some of our craters show in their interior active solfataras; others do not. White coloration of more or less intensity can, however, be produced in various ways. This will be illustrated by the following example: The crater of the Lipari Island volcano had not been in marked activity since 1771; fumaroles, however, were plentiful, and, in 1813, the expulsion of boracic acid, sulphur, ammonia, and alum was commenced. On August 7, 1873, an increased activity of the fumaroles was noticed, and on September 7th an eruption — lasting three hours — followed, covering the island with white, siliceous ashes. The main peak of the volcano and its surroundings were covered with snow-white ashes, three to four *cm.* thick. Later on, ordinary light-gray ashes fell. In subsequent eruptions, especially in 1888, pieces of lava, bleached by acid fumes, and ordinary gray ashes were thrown out.

The light color of the interior of terrestrial craters is, however, most frequently produced by the products of fumaroles, and especially by the bleaching of lavas through acid fumes.

Solfataras upon fissures are of importance for the study of the Moon. On the exterior slopes of volcanoes in Chile, which are mostly covered by snow and ice, DOMEYKO distinguishes solfataras, which occur temporarily upon long fissures; and, locally limited, permanent ones. He observed a fissure, from eight to nine *km.* long, three months after its formation, in 1847, which traversed the trachytic highlands of the Cerro Azul, in the vicinity of the inactive volcano Descabezado Grande. Steam and fumes of sulphur issued from innumerable places, and, here and there, chlorine gas. Neither liquid lava nor ashes or pumice-stone were visible. A white, earthy mass covered the rocks exposed to the reactions of the fumaroles. On a second visit, in 1857, DOMEYKO found the emission of fumes greatly reduced;

and on a third visit, in 1873, action had ceased several years ago, and the color of the fissure had become darker.

Similar long, inactive solfataric fissures are known to exist in the same mountain range. The lateral solfataras, which are located several hundred metres below the rims of craters, show neither long fissures nor forcible eruptions, and they are permanent.

Now let us consider the bright spots on the Moon. They are in evident connection with single, large craters; they appear either inside the latter or on their external slopes, or else they radiate from them in long streaks. There is no case known where white spots occur on outer slopes or radiate from the crater, unless the latter is also white.

The brightest object on the Moon is *Aristarchus*, of 35.35 *km.* diameter. In its interior, says NEISON, is a second peak, with a small crater-opening, of 9½° brightness. The interior of *Aristarchus* is fully 9½°; the west wall, 6° to 8°; the south wall, 8°; the east wall, 9°; the north wall, 9½°; and the central peak is 10° in brightness, the latter being the brightest point on the Moon.

The most remarkable phenomena on the Moon are, however, the bright systems of radiations, of more or less width, which emanate from the exterior slopes of *Tycho*, *Copernicus*, *Kepler*, and other craters, and sometimes reach a length of several hundred *kilometres*.

Without showing perceptible relief, they cross high crater-mountains and depressions, losing brightness, and disappearing finally. In single cases, they terminate on a crater; sometimes they appear to fork, but they are rarely curved. What are these white radiations?

Professor SUESS says that they are the after-effects of volcanic activity,— *i. e.*, fumaroles upon small fissures,— and that the escaping fumes have partly deposited white sublimations, but principally have caused a discoloration and bleaching of the rocks.

This hypothesis may be opposed in two ways: Firstly, that the extent of this fissure and fumarole formation is far in excess of similar phenomena on the Earth. This, however, is only a difference in degree, and not in principle. Secondly, it may be said that such extensive effects of fumaroles presuppose the existence of steam.

SAINTE-CLAIRE-DEVILLE, BUNSEN, and FOUQUÉ have found that the emanation of fumes from large streams of lava follows certain rules. At a temperature above 500° C., the escaping fumes are anhydrous. Chlorine is characteristic of this phase, and sodium-chloride is sometimes deposited upon the rough surface of the lava. The second phase, at 300° to 400° C., are the acid fumaroles,—*i. e.*, hydrochloric and sulphurous acid, with a large quantity of steam. Then, at about 100° C., appear the alkaline fumaroles with sulphuretted hydrogen, also accompanied by steam in large quantities. Then follow, below 100° C., the cold fumaroles with steam, carbonic acid, and some sulphuretted hydrogen. Finally, carbonic acid is the principal product.

Professor SUESS expresses the opinion that, in view of the great length and width (up to 30 *km.*) of some of the bright lunar radiations, and assuming that they were formed by sublimations and by bleaching of rocks, steam is indispensable for their formation, and that an anhydrous chlorine emanation alone would not suffice.

It is well known that steam plays an important part in volcanic eruptions, and it has been formerly assumed that they were caused by water entering the hot and liquid interior of the Earth. While it cannot be denied that in special cases water comes in contact with liquid lava and increases the force of explosion, another explanation, known as ANGELOT'S theory, is now generally accepted. This theory is based upon the facts that all molten masses, be they metals, glass, or slags from blast furnaces, etc., absorb various gases, which escape violently upon cooling and solidification of the magma. Thus, for example, liquid silver absorbs oxygen; copper absorbs sulphurous acid; cast-steel absorbs oxide of carbon, hydrogen, and nitrogen; slags from blast furnaces absorb air and carbonic oxide, etc. According to experiments by BESSEMER, the escaping of gases from fluid cast-steel is greatly facilitated if the castings are allowed to cool in a vacuum, which is of importance in relation to the interpretation of phenomena on the Moon. If we compare the phenomena taking place in casting steel with those observed by DANA at the Hawaiian volcano *Kilauea* (a detailed description of which would take too much space), we find a remarkable agreement of all details; whereby the supposition that both phenomena are caused by the absorption and disengagement of gases is confirmed.

Now let us return to the Moon. We not only observe the absence of water, but also the absence of even a trace of sedimentary rocks, which cover such a large portion of our planet, with their folded mountain ranges, etc. What we see on the Moon are circular forms, large ones and small ones, with here and there an ellipse or a slight deviation from a circle. That is the naked surface of a solidified, formerly liquid, heavenly body. SUESS now describes the phenomena we may expect to take place in the cooling of a fluid globe. He draws attention to the fact that after a solid crust of a certain thickness has been formed, a re-fusion of the crust takes place here and there. The shape of such a fusion-hearth, as he calls it, is that of a globe-segment, and its circumference is a circle. Now the process approaches the end; the temperature of the surface becomes less at and near the rim of the hearth; the slags are pushed outward like moraines. Finally, a level surface remains, surrounded by a circular wall of slags, which may have an attitude of several thousand feet. Such, for example, are the enormous slag-walls, — which, under the names, the *Apennines*, the *Alps*, etc., — surround the *Mare Imbrium*. One of these slag-rings, viz.: the *Alps*, is intersected by a deep furrow, which has been designated as the Great Valley of the *Alps*. This furrow is about 130 *km.* long, has, in parts, very steep, straight-cut walls, about 3000 *m.* in height, and has a level bottom throughout. It begins, 9 *km.* wide, at *Mare Imbrium*, and runs, with regularly decreasing width, to *Mare Frigoris*. SUESS explains the formation (according to the last-taken P. W. photograph of the *Alps*), by assuming that the whole slag-field was broken from the east, and that the two fragments were horizontally pushed against each other. Such occurrences presuppose great mobility of the substrata, which is in harmony with what has been said about the fusion-hearths.

After the slag-crust on the surface of the Moon had increased in thickness, — this slag-crust will be designated in future as the lunar *lithosphere*, — the fusion-hearths were greatly diminished in diameter, and now gave rise, not to large *mare* formations, but to smaller rings, craters, and volcanic mountains. There is no doubt that the majority of the now existing craters are of more recent origin than most of the *mare* flats. Every one of these abysses is evidently an independent fusion-hearth. After renewed fusion of the lithosphere by internal heat, the escaping gases caused a pushing back of the solid slags, and, as a rule, an overflowing of lava. This process may have been repeated several times in the same crater.* As a rule, the bottom of the crater, as we see it now, is far below the average level of the surroundings. An exception, however, is formed by *Wargentin*, in which the lava has solidified near the rim of the crater, high above the surroundings. The depth of craters evidently depends upon the slower or quicker escape of gases, and sometimes upon lateral drainage of lava. EBERT has measured 92 of the lunar crater-mountains, and found that the slope of their exterior profiles is from 6° to 12°. Only *Plato* and *Tycho* are considerably steeper.

It is interesting to notice that, of terrestrial volcanoes, *Mauna Loa* has a slope between 3° 51′ and 6° 43′; and the Iceland volcanoes show still flatter angles. The interior slope of lunar craters, on the contrary, is very steep; as a rule, over 30°, often 40°, and for *Aristarchus* as much as 55°.†

The depth of lunar crater-bottoms below the immediate surroundings is rarely less than 500 *m.*; in most cases, 1000 to 2000 *m.*, and reaches in *Maurolycus* 3031 *m.*; in *Theophilus* 3411 *m.* In the latter crater, of 102.7 *km.* radius, the bottom is 4678 *m.* below the rim, and from the bottom rises a central peak, 2144 *m.* high. The bottoms of *Werner*, *Tycho*, and others are also over 4000 *m.* below their rims.

A peculiar phenomenon on the Moon is the frequent occurrence of groups of large craters. *Catharina*, *Cyrillus*, and *Theophilus*, for example, stand close together, and *Theophilus* extends far into *Cyrillus*. Why was the older crater inactive and a new one formed in close proximity? Terrestrial experience has taught us that isothermal lines run nearly parallel near the surface, but only reach full parallelism at greater depths. Now, if the lava in a crater of large dimensions has once completely solidified, the isothermal line is lower in this particular spot than in its vicinity, and renewed volcanic activity,—*i. e.*, a new supply of internal heat,—does not find the point of least resistance below the dead volcano, but in its immediate vicinity. The Hawaiian volcanoes, *Kilauea* and *Mauna Loa*, however, show that two adjoining volcanoes can be in activity simultaneously.

The lunar formations described had the following characteristics:

---

* See HOLDEN, *Publications* A. S. P., Vol. III, page 250.

† See BECKER, geometrical form of volcanic cones, and the elastic limit of lava, *Amer. Jour. Sci.*, October, 1885.

First. — Their circumferences were circular, elliptic, or irregularly elliptic.

Second. — They had plainly visible walls, more or less flat on the outside, and steep inside.

Third. — They had well-defined, level, or slightly curved bottoms. Only to these the name of crater should be applied. They can be compared with terrestrial volcanoes of the Hawaiian type, and differ from the latter:

First. — In regard to their greater dimensions.

Second. — That their bottoms are considerably below the average level of immediate surroundings.

Third. — By the rarity of internal ruptures.

The surface of the Moon shows, however, many other forms which differ materially from those so far described; they are located partly inside and partly outside of craters.

Ptolomaeus (L. W. and P. W.), for example, shows upon a wide and nearly level lava-plain the so-called crater A., a circular opening, without visible bottom, upon a conical peak. Close to the north is a cup-shaped depression. In a terrestrial lava-field it would be said that such a depression was formed by the escape of a big bubble.

Sometimes two openings upon so-called central mountains are close together, as, for example, southeast of *Archimedes*, near the rim of *Mare Imbrium;* and sometimes they appear in the form of a figure 8. In *Clavius* such openings appear in great number, but separated. These bubble-like openings have so far all been designated as craters, which does not seem proper. So far as dimensions are concerned, their diameters may be as much as 15, and even 18, *km.*

SUESS expresses the opinion that their formation is due to a single explosion. They are a subject for further investigation.

In September, 1783, a long fissure was formed in the volcanic regions of Iceland, not radiating from a main crater, but belonging to a system of fissures, which, following a curved depression, traverses the whole of Iceland. It has been called the *Laki* fissure, because it intersects the mountain *Laki.* THORODDSEN followed this fissure for about 30 *km.*, and found it disappearing to the northeast in the ice-fields of the *Skaptar Jökull.* All along the *Laki* fissure are crater-cones, of which the highest is only 150 *m.* THORODDSEN counted about 100 of them. They have been formed by the throwing up of slag and ashes; from them, as well as from the fissure itself, enormous masses of lava have escaped.

The surface of the moon shows formations that remind us of the *Laki* fissure. They have evidently been formed not by fusion, but after the lunar lithosphere had become more solid. JUL. SCHMIDT has called them crater-rills. In recent (L. W.) photographs, the most remarkable of these formations runs near the south base of *Ptolemaeus*, and at least eight places of eruption have been counted on it.

While their connection with fissures is undoubted, it is not yet known whether cones exist upon lunar crater-rills or only funnels. Here is room for further observation.

Another peculiar phenomenon is presented by the high ridges traversing the *Ariadaeus* fissure: some of the ridges are intersected by the latter, and others are not. (P. W.) Here it might become possible to decide whether lava-streams of great length have flowed upon the Moon.

In concluding his interesting paper, Professor SUESS makes the following suggestions:

First. — Some observers say that bright streaks on the Moon appear differently on the photographs, and as seen by direct vision. A comparison with photographic effects of light-colored terrestrial volcanic products would be desirable.

Second.—The construction of the lunar Alpine Valley, especially its western half, is of such importance for the study of large slag-fields that its details should be observed with great care.

Third.— Of equal importance in other respects is the study of *Wargentin.* This crater, with its sea of lava solidified while the latter was overflowing, is unique on the Moon.

Fourth.— Between the fusion-craters with flat bottoms and the explosion openings we find two doubtful types. The one — for example, *Alpetragius*, — seems to have a certain similarity with Vesuvian structures. An accurate determination of the slopes of *Alpetragius*, the condition of its central opening, etc., is desirable. The second type comprises openings like *Ptolemaeus A.*, which have been compared with bubbles, and are of unknown origin.

Fifth.—The majority of openings upon fissures do not seem to possess walls. It would be of importance to know whether anywhere a cone exists upon a fissure. Besides, it should be determined for large fissures whether ridges intersect them uninterruptedly in such a manner that the existence of comparatively recent lava-streams could be assumed.

No one can deny the importance of the study of lunar phenomena in relation to terrestrial geology. We see here, as it were, our own globe in its infancy. In both celestial bodies the following phases can be classified:

I. Fusion of the lithosphere in large plains. (*Mare Serenitatis;* not observable on the Earth.)

II *a.* Fusion without reaching the surface. (*Batholithes*, granite of the *Erzgebirge;* not known on the Moon.)

II *b.* Fusion-hearths of small diameter; quiet boiling of lava. (Hawaiian volcanoes: *Ptolemaeus*, *Wargentin.*)

III. Formation of fissures, narrow chimneys, and rhapsodic explosions. (*Laki*-fissure, *Vesuvius;* crater-rills, *Hyginus.*)

Finally, as local consequences of single eruptions, we mention the different phases of fumaroles which have been assumed to exist on the Moon also.

PLANET NOTES FOR JULY AND AUGUST.

By Professor Malcolm McNeill.

July.

Mercury passes inferior conjunction with the Sun on the morning of July 1st, and becomes a morning star. It moves rapidly away from the Sun, and reaches west elongation on the evening of July 22d. For the rest of the month it rises a little less than an hour and a half before the Sun, and is in good position for observation.

Venus is in good position for evening observation. It reaches greatest east elongation, 45° 31′, on the morning of July 11th. It then remains above the horizon 2^h 20^m after sunset. This is not as long as it was during June, although the distance from the Sun is greater. This shortening of the time between sunset and the setting of the planet is due to the fact that the planet is far to the south of the Sun; and the difference of declination increases throughout the month, so that on July 31st the planet sets less than two hours after sunset.